SAND2019-9317PE

High-resolution additive manufacturing of porous metal structures for chemical engineering applications

PRESENTED BY

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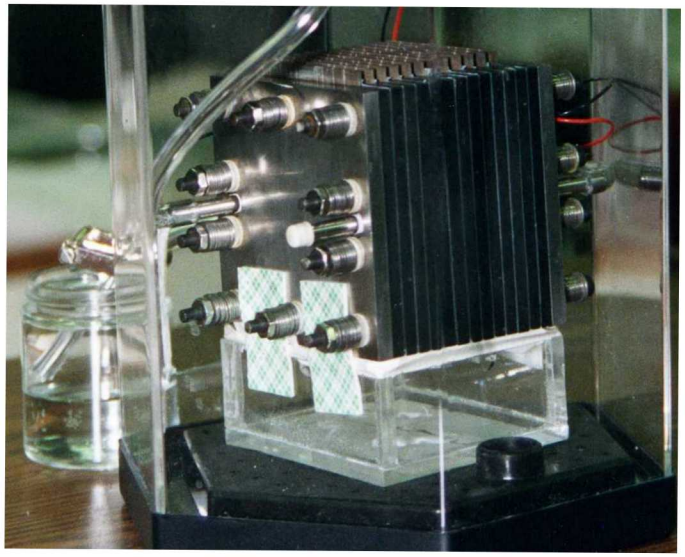
Hierarchical pores aid multiphase transport

- Technologies like batteries, fuel cells, heat exchangers, and catalytic converters require transport of a fluid through a stationary phase.
- High surface area between phases ➔ small pores
- Rapid fluid transport ➔ large pores
- 3D printing offers deterministic, optimal pore structures



http://www2.jpl.nasa.gov/files//images/hi-res/p48600ac.tif

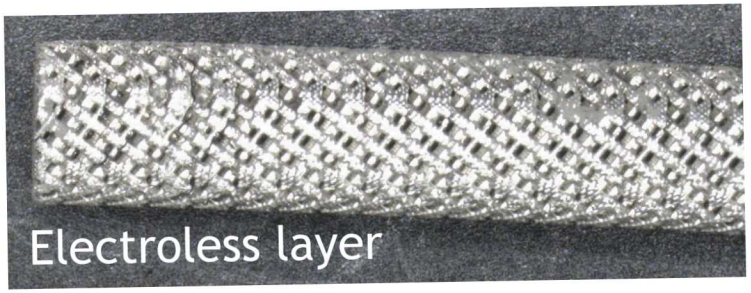
"Pot catalytique vue de la structure" by The RedBurn - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Pot_catalytique_vue_de_la_structure.jpg#/media/File:Pot_catalytique_vue_de_la_structure.jpg

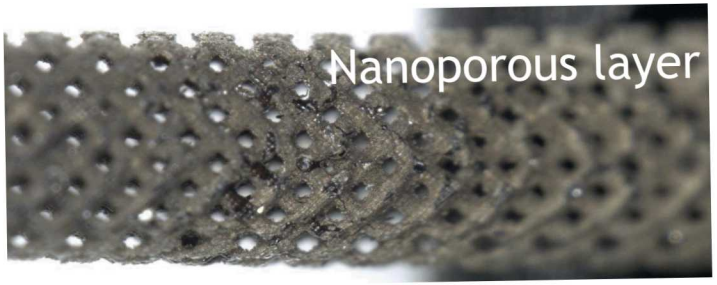
3D-printed polymer templates enable hierarchical porosity

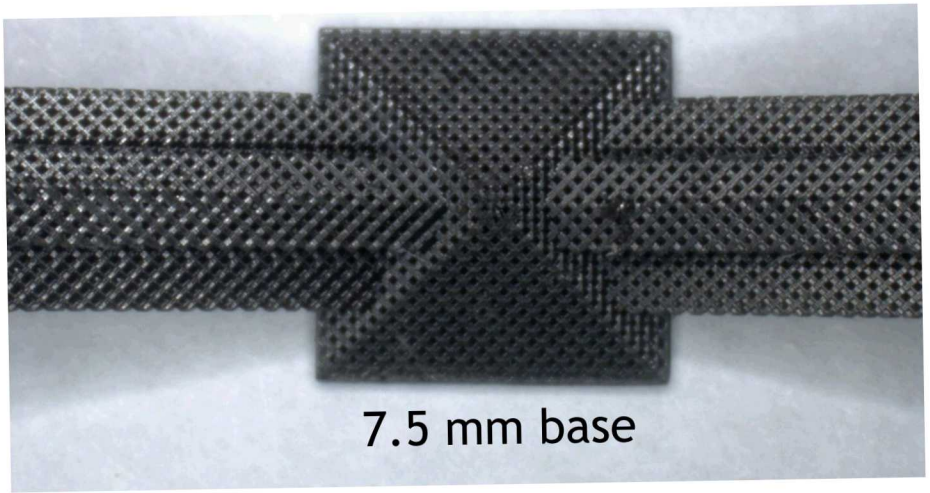
Autodesk Ember

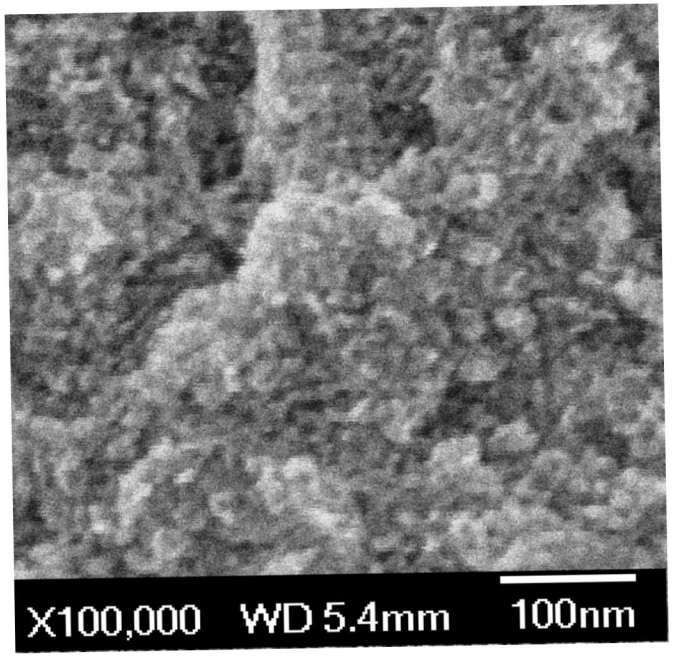
Desktop photopolymer printer makes cm-scale parts with 100 μm-scale pores on a timescale of a few hours.

Polymer-templated electrochemical deposition creates nanoporous metal layer.









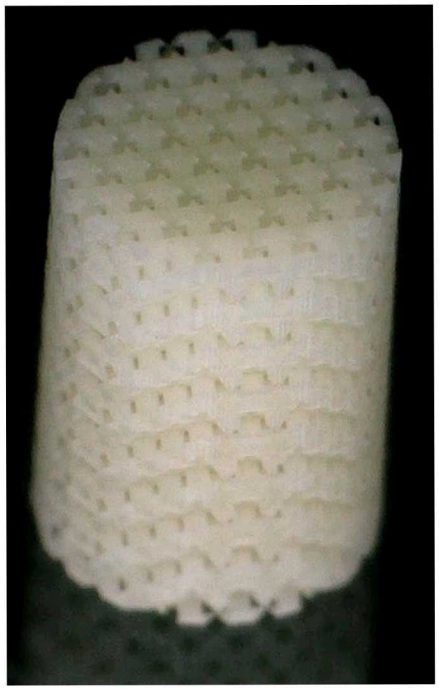
Advanced polymer printers bridge 100 nm to 100 µm scales

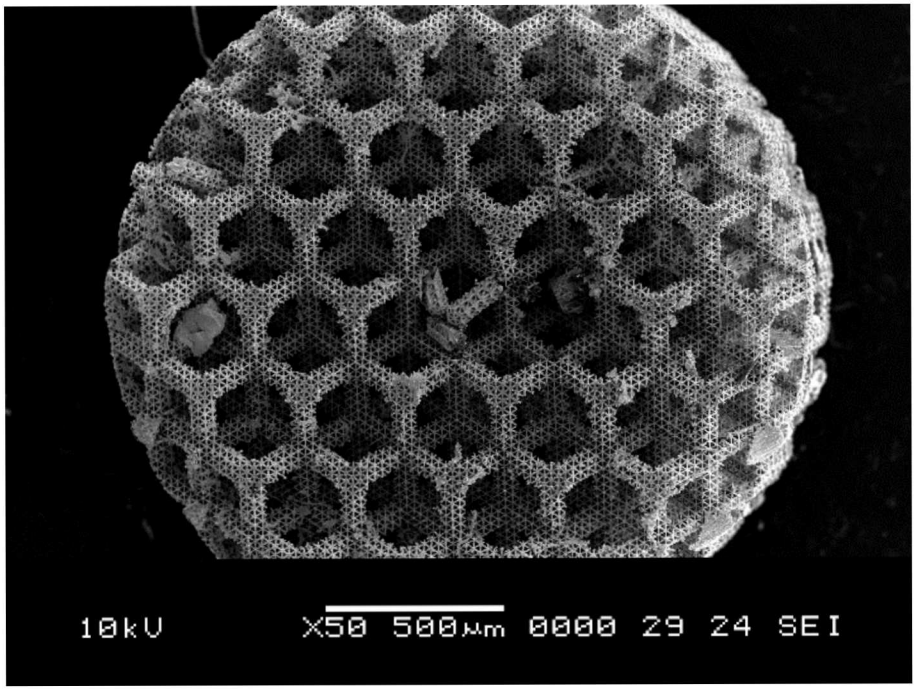
Two-photon polymerization tool allows printing of mm-scale objects with 100- and 10-µm scale pores on a timescale of 1 day.

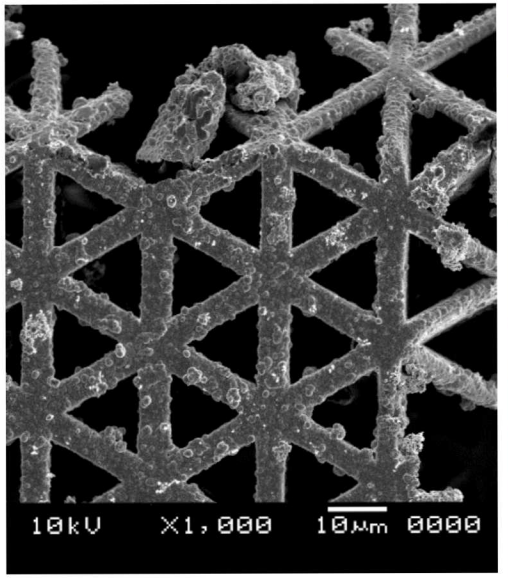
These can be coated with porous or nonporous metal. LLNL/MIT and Carbon 3D technologies may allow faster printing.

Zheng et al., Nature Mater. 2016

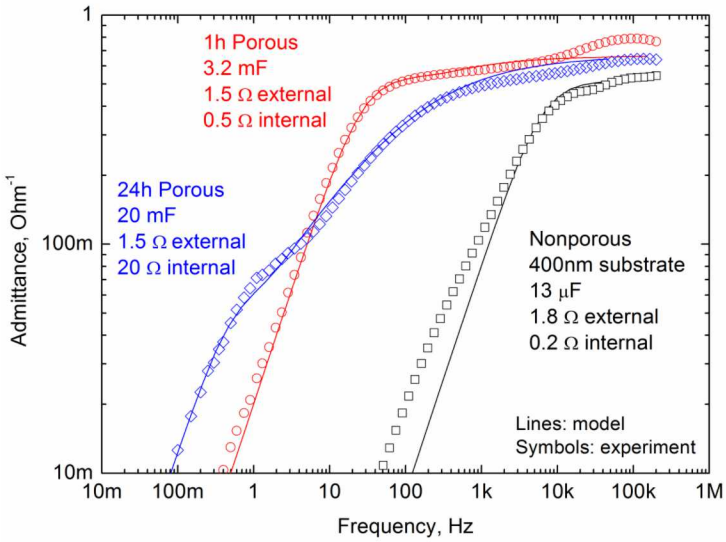
Janusziewicz et al., Proc. Nat. Acad. Sci. 2016





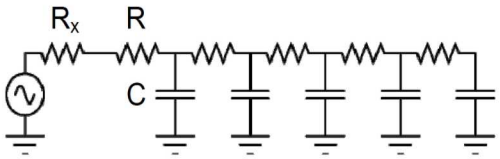


Pore hierarchy enhances electrochemical capacitor charging rates



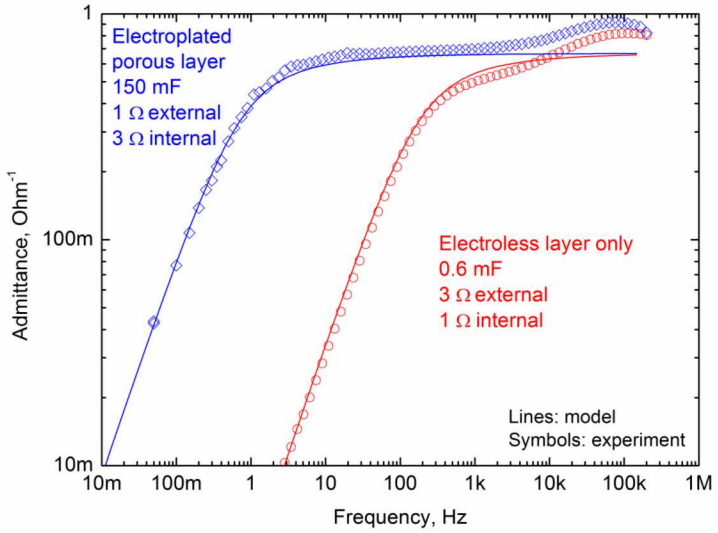
Planar nanoporous film becomes slow when too thick

Goal is to move knee in charging curve left and up

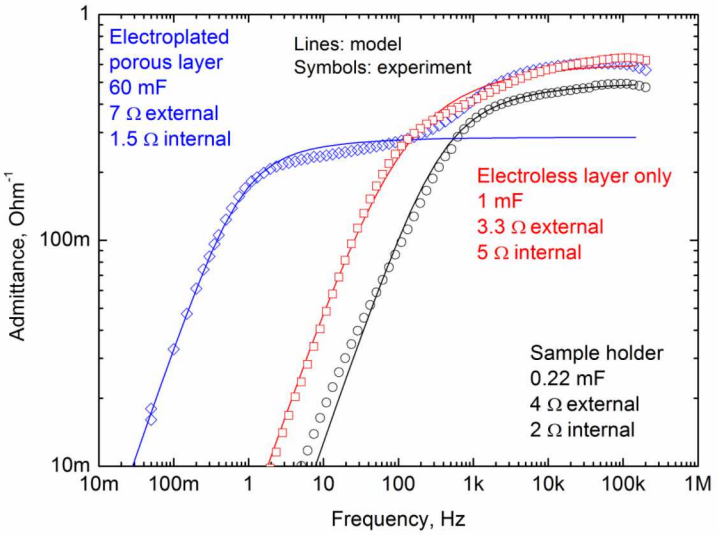


R_x - resistance external to pore
R - resistance internal to pore
C - pore capacitance

Pd in 1M sulfuric acid



Ember part (above) and Nanoscribe part (below) accomplish this



Salloum and Robinson, AIChE Journal 2018

Jones, Mills, Nishimoto Robinson. J. Electrochem. Soc. 2017

Possible future research/discussion topics

- Are there ways to improve spatial resolution of 3D printing by laser melting/sintering?
  - Roy et al., JOM 2019 (M. Cullinan group, UT-Austin)
- Can partial melting/sintering allow tailored porosity?
  - Mott Corporation achieves this with specialized powder and printing conditions
  - Palumbo et al., US patent application 2017/0239726 A1
- Are there other ways to transmute high-resolution polymers to metal?
  - Cast metal into polymer-derived ceramics?
  - Eckel et al., Science 2016 (HRL Labs)

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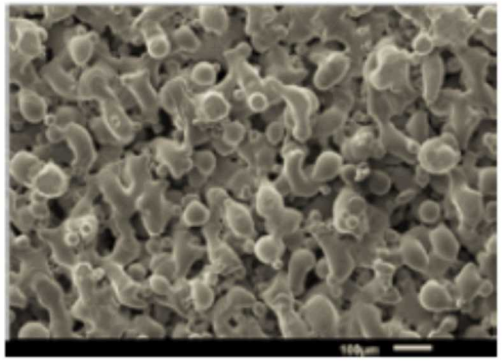
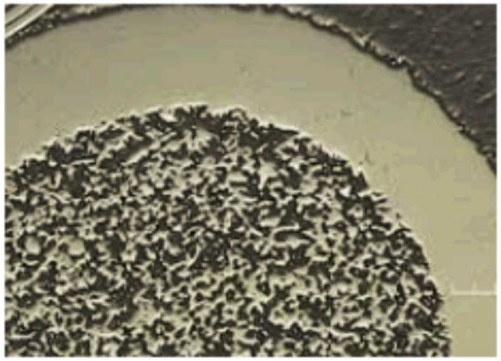


3D Printed Porous



Porous-to-Solid

Mott 3D-printed porous products brochure

mottcorp.com